

VOLUME 14

PART 1

MEMOIRS
OF THE
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BRISBANE



VOLUME 14

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OPAL PHYTOLITHS FROM SUGAR CANE, SAN FERNANDO, PHILIPPINE ISLANDS

GEORGE BAKER

Mineragraphic Investigations, C.S.I.R.O.,
University of Melbourne

ABSTRACT

The ubiquity of opal phytoliths and their abundance in several plants used extensively by man and other animals is gradually becoming more widely known; their probable importance to the health of man is treated herein from one particular aspect, that of the sugar cane industry. Many of the larger opal phytoliths in sugar cane plants from the Philippine Islands are crushed during cane processing, forming numerous small fragments, while the smaller examples frequently escape fracture during crushing. Dust-size particles are produced, and their size, shape and specific gravity allow them to become readily airborne and thus available for inhalation with vegetable dust, more especially by sugar cane processors and others handling the bagasse. Hard, sharp, minute solid particles of mineral matter ranging down to half a micron and less in size are thus made available from sugar cane fibre to penetrate and impair pulmonary cells. Because of their more resistant nature relative to the organic constituents of the sugar cane dust, they persist much longer and possibly cause blockages leading to the impairment of lung elasticity.

INTRODUCTION

Specimens of sugar cane plants from San Fernando, Province of Pampanga, Island of Luzon, Philippine Islands were crushed in assay laboratory rolls to dispose of the juice. Di-acid digestion of the bagasse resulting from this treatment yielded a siliceous residue free from all traces of organic constituents. It was prepared through the courtesy of K. J. Callow, in September, 1960, in the laboratory of Benguet Consolidated Inc., Luzon, Philippine Islands.

The samples of sugar cane selected for treatment assayed 0.67 per cent. SiO_2 (dry weight). Inspection under the petrological microscope revealed that the SiO_2 was in the form of opal phytoliths (plant opal, which is amorphous silica). The water content of the opal phytoliths was not determined by this assay, but was assessed by means of refractive index determinations, and determined from loss in weight on 23 milligrams by semi-micro-analysis of the residue obtained by acid digestion.

MATERIAL

The sugar cane (*Sacharrum officinarum*) is one of the larger perennial grasses growing well in regions where the average yearly rainfall is 60 inches. It grows to a height of 8 ft. to 20 ft. and has stems up to 2 in. diameter. The stems have alternating nodes with internodes up to 10 in. long and averaging 6 in. long. The hard outer rind of the stem carries much of the opaline silica and encloses a mass of softer tissue within, interspersed with fibro-vascular bundles. Since the grass tribe is renowned for its silica-accumulating properties, it is not surprising to find that opal

phytoliths are relatively common constituents of the sugar cane. In fact, it has been recorded that on some of the sugar plantations in Hawaii (Moir, Hane, *et al.*, 1936, p. 134) the sugar cane takes up approximately 1,700 pounds weight of silica per acre in two years; most of this silica is precipitated as solid, not easily soluble siliceous phytoliths composed of amorphous silica; this rate of uptake and precipitation is very fast.

The canes are crushed, torn into small pieces and passed through three sets of rollers to extract the juice. This process releases and fractures the opal phytoliths, creating numerous small fragments of solid amorphous silica. The dry residue, which is known as bagasse, can be used as a fuel, and for making paper and thermal and acoustic insulating boards. The dust from this dry residue causes bagassosis, an acute bronchiolitis and broncho-pneumonia, with a mortality of approximately 5 per cent.

It is known that bagasse contains many fungi, including *Aspergillus*, and the suggestion has been advanced that these or their breakdown products may be the cause of a type of pneumoconiosis which is very similar to that of a lung disease occurring in workers with hay and grain in Cumberland, England, where susceptibility occurs at certain times of the year. Such are times when the silica in the plants constituting the hay has virtually all been precipitated in the solid form as opal phytoliths.

The fungal or bacterial origin of these conditions is not yet proved, and it has been suggested that they may just as easily be of mechanical origin, whereby the vegetable debris blocks the bronchioles and causes small areas of collapse which may later become infected.

The main object of this paper is to draw attention to the nature and characteristics of the solid particles of opaline mineral matter contained in the bagasse. So far as the author is aware, opal phytoliths and the details of the forms that they assume have not been recorded as the characteristic specific forms in which vegetal silica occurs in the sugar cane. Furthermore, their presence has not been considered relative to their potentialities as primary causes of cell damage, as a result of which, all subsequent effects of pneumoconiosis would evidently be purely secondary or tertiary in character.

OPAL PHYTOLITHS

The opal phytoliths constituting the siliceous residue from di-acid digestion of sugar cane bagasse from the Philippines do not reveal the range of shape types encountered in (i) soils, dusts, rainwater, tapwater, snow, hail and plants (more especially members of the gramineae) that have been studied in some detail in Australia (Baker, 1959a, 1959b, 1960a, 1960b, 1960c), or in British soils (Smithson, 1958).

PROPORTIONS OF SHAPE TYPES

The opal phytolith assemblage is a relatively simple one (Plates I–III), and the most typical shapes are (*a*) hat-, stud-, and spool-shaped forms (figs. 10, 16–19), and (*b*) smooth, slender, narrow (fig. 1) and broader (fig. 8) rods, some of which are needle-like (figs. 2 and 5), others of which have sharp-pointed outgrowths (figs. 3 and 6). These rods range in length from 0.025 mm. to 0.700 mm.; their widths vary from 0.005 mm. to 0.035 mm., and they are invariably thinner than wide. They represent internal casts of plant cells of varying length and width, the lumens of which have been partially or completely infilled with solid opaline silica.

The crushing of the sugar cane resulted in the generation of a considerable proportion of fragments among the opal phytolith assemblage (see Table 1). Many of these are small, some being lancet-like splinters down to 0.001 mm. wide; others are more angular fragments under half a micron in size.

A count under the petrological microscope, at magnifications of 505 x, of the various types of opal phytoliths mounted in Canada balsam of $n = c. 1.54$, revealed the proportions listed in Table 1.

TABLE 1

Per cent. by count of the shape types of opal phytoliths in a silica residue obtained from sugar cane grown in the San Fernando district, Province of Pampanga, Luzon, Philippine Islands.

Shape Type								Text Figure Number	Per cent.
Smooth, slender rods	..	..	..	..	..	..	..	1	2.2
Smooth, broader rods	..	..	..	..	..	..	..	8	1.4
Smooth, pointed rods..	..	..	..	..	..	..	..	2, 5	0.3
Serrated rods ..	..	..	..	..	..	..	..	9, 14	0.2
Thin plates ..	..	..	..	..	..	..	..	..	0.4
Hat-, stud-, and spool-like forms	..	..	..	..	..	..	..	10, 16–19	14.9
Dumbbell-shaped forms	..	..	..	..	..	..	..	15	0.2
Nondescript shapes ..	..	..	..	..	..	..	..	11	1.5
Small fragments ..	..	..	..	..	..	..	..	..	78.8
Composite*	..	..	..	..	..	..	..	..	0.1
Total ..	..	..	..	..	..	..	..	..	100.0
Number Counted	..	..	..	..	..	..	..	..	1,522

* Composite types represent the aggregate of silica-replaced cells showing two or more cells.

(Note. Weight and volume percentages are impracticable to assess for each shape type because of the size range of the opal phytoliths. The largest numbers (principally fragments) are only about 0.005 mm. in average size, ranging down to under half a micron; others, such as those depicted in the text figure, are much larger.)

FORMS

A feature of the non-pointed, rod-like opal phytoliths (Plate I, B) is that the majority have smooth surfaces, and few are rugose with rough to spinose surfaces. (Plate III, C). Most tend to be rather more angular rods than is usually observed in

Australian specimens of the gramineae. This is due to them being faceted and ridged (figs. 1, 2, 4, and 8), and in planes normal to their long axes they are frequently square to rectangular, rarely approximately hexagonal (e.g. in the broader forms) in outline. Such types therefore possess sharp solid edges where two faces meet along their lengths, in addition to sharp solid angles at their ends where three faces intersect. A few are circular to oval in cross section. Rare examples with scalariform structures (fig. 9) evidently represent partially infilled portions of conducting vessels.

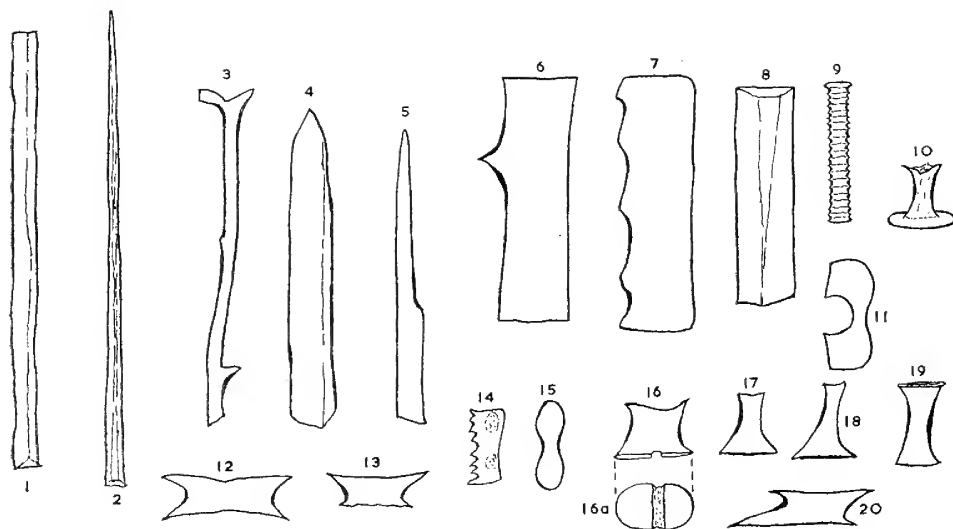


Figure 1

Diagrammatic two-dimensional sketches of opal phytoliths from sugar cane, Luzon, Philippines (all $\times 406$ unless otherwise stated).

1. Long, slender, smooth rod with ridge ($\times 146$).
2. Long, slender, tapered rod ($\times 91$).
3. Slender, rod-like form with outgrowths.
4. Shorter, rod-like form with pointed termination.
5. Slender, shorter rod with one end tapered.
6. Broader rod with spinose outgrowth.
7. Broader rod with one of the longer edges crenulated.
8. Facetted, angular rod.
9. Serrated rod with small annular ridges.
10. "Collar-stud"-like form.
11. Nondescript form.
12. Anvil-like form.
13. Boat-like form.
14. Short rod serrated on one of the longer edges and showing two small patches representing attachment areas.
15. Dumb-bell-shaped form.
- 16-18. Hat-like forms of slightly varying height and width.
- 16a. End aspect of No. 16, showing "slotted" character.
19. Spool-like form.
20. Distorted anvil-like form.

The more common but much smaller hat-, stud-, and spool-shaped opal phytoliths (cf. Smithson, 1958, p. 152 ; Baker, 1959a, 1959b, 1960a, p. 33, 1960b, p. 81) average approximately 0.012 mm. by 0.015 mm. in size. A few of the stud- and spool-like forms are more slender than shown in figs. 12, 13 and 16-20, and sometimes crudely resemble four-rayed stars with sharp, small points (cf. Plate I, A). In plan aspect, most of the stud- and hat-shaped forms are notched like the head of a screw (see fig. 16a, and Plates II and III).

Nondescript shapes average 0.020 mm. across. Dumb-bell-shaped forms (fig. 15) are 0.028 mm. long and up to 0.010 mm. across their bulbous ends. A few of the nondescript shape types and some tabular plates are occasionally so thin as to be almost phantom-like and only just discernible in the Canada balsam mounting medium (Plate I, C and Plate III).

One slightly curved plate of colourless opal measures 0.05 mm. by 0.03 mm. in size and possesses approximately 70 minute rod-like outgrowths 0.003 mm. long and 0.0007 mm. in diameter. These outgrowths are all about the same size and arranged in gently curving rows on one surface of the plate ; they are spaced 0.0015 mm. apart in the rows, while the rows themselves are 0.003 mm. apart. The structure resembles a miniature " rasp ".

The assemblage of opal phytoliths is constituted of different micro-forms in such proportions and of such shapes that the individuals are likely to pack together into aggregates under given circumstances, once a few become " anchored " among soft tissues ; the chances of blockages arising on this basis are relatively high. The rods and splinters of various sizes will not always necessarily be maintained in streamlined positions under all circumstances. By analogy with the manner in which some low grade varieties of diatomaceous earth cake during use to reduce their filtering qualities, so is it possible for the rod-like and splinters of opal phytoliths to become jammed in criss-cross to random haphazard arrangements. Such arrangements are then suited to trapping and mechanically entraining smaller forms and fragments to ultimately form a conglomeration of loosely or more tightly packed solid opaline micro-bodies.

Furthermore, the smaller of the sharp, narrow, needle-like forms (Plate III, A and B) and micro-splinters fractured from larger forms could penetrate cell walls equally as readily as an ordinary needle penetrates thin-skin membranes. The pavement epithelium cells lining the alveoli of the lungs form an extremely attenuated membrane through which rapid gaseous exchange is facilitated between the alveolar air and the blood in the lung capillaries. Such tissue would be vulnerable to impalement and damage by certain shape types of opal phytoliths, once they are brought to bear on these sites. The same could apply to other membranous tissues such as those

of the ciliated epithelium lining the cavities of the nose, the trachea and the bronchi, where the cilia "beat" in a definite direction producing wave-like surface movements sufficiently strong to carry along particles lying in contact with them. The possibility of certain shape types of opal phytoliths being responsible for the primary causation of cell damage in the pulmonary apparatus can no longer be overlooked in view of recent research work that has shown their importance in herbivorous animals such as the sheep (Baker, Jones and Wardrop, 1959, 1961; Baker and Jones, 1961; Baker, Jones and Milne, 1961). The presence of opal phytoliths as the vegetal silica in plant dusts, the shapes of certain of these phytoliths and the incidence of pneumoconiosis in workers handling plant material, such as the bagasse from sugar cane, should stimulate revival of the mechanical theory of primary causation of certain types of pneumoconiosis (cf. Baker, 1961).

OPTICAL PROPERTIES AND WATER CONTENT

The smaller forms and the fragments of opal phytoliths are virtually colourless, the thicker and larger forms and fragments have a very pale brownish tint in transmitted light. In reflected light under the petrological microscope, a few of the larger forms reveal an opalescent translucency in greyish-white to white. The long, slender, needle-like form (figure 2) is opalescent at the tapered end, but colourless and transparent at the broader end. The greater proportion of the opal phytoliths are hyaline and hence comparable with the *hyalite* variety of opal.

The refractive index values have been determined by the Immersion Method and show a range from $n_{Na} = 1.438 \pm 0.001$ to $n_{Na} = 1.448 \pm 0.001$. This is a rather smaller range than that determined for hook-shaped opal phytoliths ($n_{Na} = 1.430$ to 1.452) from the epidermal cells of oats grown on basaltic soil in Victoria (Baker, 1960e). The hat-shaped and allied forms, also some of the smaller needle-like examples (0.010 mm. by 0.0025 mm. in size) usually have $n_{Na} = 1.448$, but this value is a little too high for most of the larger rods. The thin plates and the broader types of rod-like forms have the lower refractive index value ($n_{Na} = 1.438$). Many of the larger, more slender rods have $n_{Na} = 1.442 \pm 0.001$.

On the basis of refractive index variation with the water content of opal, the range in the index values for the opal phytoliths from the Philippines sugar cane bagasse indicates a range in water tenor of from 11.2 per cent. in the thin plates and broader, thin types of rods down to 7.8 per cent. in the hat-, stud-, and spool-shaped forms and also in some of the more slender of the larger rods.

COMPOSITION

The composition of the vegetal silica free from organic matter has been determined by semi-micro-analysis of a representative sample of residue obtained by di-acid digestion of the bagasse resulting from passing sugar cane plants through assay laboratory rollers. The constituents present are listed in Table 2.

TABLE 2

Chemical composition of vegetal silica from sugar cane bagasse, San Fernando district, Province of Pampanga, Luzon, Philippine Islands.

—	Per cent.	—	Per cent.	—
SiO ₂	82.8	H ₂ O (+) ..	11.4	(Anal. P. J. Sinnott)
Al ₂ O ₃	0.55	H ₂ O (—) ..		
Total Fe as Fe ₂ O ₃ ..	1.20	TiO ₂ .. .. .	..
MgO .. .. .	..	P ₂ O ₅	0.03
CaO .. .. .	..	MnO .. .. .	..
K ₂ O	0.65	Li ₂ O	Nil	
Na ₂ O	0.28	.. .. .	..
		Total	96.91*	

* Insufficient material for complete analysis.

The chemical analysis and examination under the petrological microscope of portion of the representative sample analysed confirm that the phytoliths are fundamentally opaline silica, approximately 94 per cent. of the siliceous residue being SiO₂ plus H₂O (see Table 2).

RESIDUE FROM BURNING THE BAGASSE

The burning of the bagasse as a fuel in the furnaces of the Pampanga Sugar Development Company's refinery at San Fernando results in the production of a pale pinkish-white, friable, sintery residue containing more highly vitreous, cylindrical areas of very pale bluish-green colour (Plate IV). This product, in which the water content is reduced to under one per cent., consists principally of SiO₂, and it originates from fusion of the opal phytoliths in the bagasse and from fusion of small amounts of other compounds, some of which are introduced from adventitious soil and dust particles mechanically entrained with the bagasse.

Analyses of the furnace sinter reveal the proportions of constituents shown in Table 3.

TABLE 3

Chemical composition of the sintery "furnace silica" obtained on burning bagasse, San Fernando, Luzon, Philippine Islands.

	Per cent.	
	I	II
SiO ₂	70.48	69.6
Al ₂ O ₃	1.01	4.20
Fe as Fe ₂ O ₃	1.70	1.56
MgO .. .. .	..	3.62
CaO .. .. .	..	4.00
Na ₂ O	Not determined	0.78
K ₂ O	Not determined	11.37
P ₂ O ₅	Not determined	4.30
Li ₂ O	Not determined	Nil
TiO ₂ .. .. .	..	0.13
H ₂ O (±) .. .. .	..	0.25
MnO .. .. .	..	0.08
Total	73.17	99.89

I—Partial analysis by the assayer at Benguet Consolidated Inc., Philippine Islands.

II—Analysis by A. W. Hounslow, in the laboratories of the Mineragraphic Investigations Section, C.S.I.R.O., University of Melbourne.

Examination of a Canada balsam mount of crushed fragments of the friable sinter under the petrological microscope reveals an almost colourless, transparent to translucent, isotropic glass showing no evidence of strain, with rare non-fused refractory grains that were evidently derived adventitiously from soil or dust caught up in the bagasse. There was scant evidence in the portions of the sinter examined that many of the opal phytoliths had escaped fusion; a few partially fused remnants of the thicker types of rod-shaped forms were observed.

Smaller specimens of the "furnace silica" bear a superficial resemblance to fulgurites, more especially from the aspect of their rugosity and the elongate cylinder-like nature of parts. Such parts tend to be more solid and cylindrical or rope and reveal vesicles up to 2.5 mm. across at their broken ends; their outer walls show a sub-vitreous to vitreous lustre which contrasts with the much duller overall lustre of the off-white sinter in which they are embedded.

From the optical examination and the chemical analysis (Table 3), it is concluded that the sinter is essentially a potassium-rich glassy product derived from the fusion of opal phytoliths and potassium salts, with little accompanying sodium salts, contained in the bagasse. Some of the iron and alumina present could derive from the adventitious mineral matter entrained as dust or soil particles in the bagasse samples.

RESIDUE FROM PARTLY BURNED BAMBOO

It is of interest to note that bunches of apparently fibrous masses occur associated with burnt pieces of bamboo in the same area from which the sugar cane was investigated. These masses resemble "mountain leather" in appearance, but are

much harsher to the touch. Examination under the petrological microscope reveals that they consist of numerous long, thin needle-like opal phytoliths. They formed the siliceous skeleton of the bamboo, and were not fused by the partial burning of the bamboo. This occurrence indicates that in areas where the bamboo also is burned, abundant needle-like opal phytoliths may be released and made available in dust for inhalation by local inhabitants.

CONCLUSIONS

It is now becoming more and more evident that microscopic forms of opaline silica precipitated as minute solid bodies in many plants, more in some than in others, can have an important bearing on the well-being of man and animals. (cf. Baker, Jones and Wardrop, 1959, 1961 ; Baker and Jones, 1961 ; Baker, Jones and Milne, 1961 ; Baker, 1961).

Opal phytoliths are ubiquitous ; on being shed or otherwise released from plants (cf. Baker, 1959a, 1959b, 1960c ; Smithson, 1958), or passed out in countless thousands in the complete or fractured state in the faeces of herbivorous animals, they become added to dusts (Baker, 1960a), and included in rainwater, hail, snow and ice. They are thus available in several milieus to be introduced by various means into the human and other animal systems.

Although the sintery product resulting from burning sugar cane bagasse in the sugar refinery furnaces at San Fernando in the Philippines is mainly very friable, and on finger pressure some parts yield small, sharp fragments of a potassium-rich glass, it is less likely to result in the quantity of dust particles arising from the bagasse itself, in which the opal phytoliths become concentrated.

The dried bagasse provides many small, sharp, often needle-like particles of opal (Plates I to III) with the necessary physical properties to allow them to pass into the lungs, impair cells and hence cause a fibrous tissue reaction. The opal particles are likely to be infinitely more resistant to biochemical attack in the body than are the plant tissues with which they may be associated in composite particles (i.e. plant tissue with unreleased opal phytoliths still *in situ*), and so may be inhaled in composite particles and later released with the disappearance of the plant tissues. Many, however, already exist as freed phytoliths and fragments thereof ; many are of a size and shape to become airborne in dust, and if sufficient become inhaled, such micro-bodies of opal could in time impair lung elasticity, since the lung is not expected to act as a dust trap physiologically.

The mechanical theory of causation of the fibrosis associated with many forms of pneumoconiosis has been considered in the past as a possibility, but was largely abandoned to be followed later by the adoption of a solubility theory relative to the inhalation of particulate silica. This, however, did not give all the answers and later theories advocated that fibrosis associated with the presence of free silica in tissues is due to auto-immune reaction.

Small, solid, sharp particles of opal are harder than the hardest known animal tissues such as sheep's teeth (cf. Baker, Jones and Wardrop, 1959) and hence very much harder than pulmonary cells. They range down to minute sizes, so that the size factor is favourable to their becoming introduced into various parts of animals (cf. Baker and Jones, 1961). They have shapes and a specific gravity which make them amenable to ready streamlining when brought into motion. They are known in parts of the animal body where pressures are brought to bear so that this motion can be achieved. They are relatively resistant to chemical attack and have not yet been observed to reveal evidence of chemical corrosion in any of the several sites in the animal body where they have been observed *in situ*. Many have shapes with outgrowths and protuberances, sometimes minute hook-shaped processes that would enable them to become anchored in certain situations and difficult to remove. These properties indicate that the mechanical theory of causation may explain some forms of pneumoconiosis. In its application to bagassosis it is shown in this article that a supply of small, hard and sharp micro-bodies (opal phytoliths) of the right size and shape are available for inhalation by workers with bagasse. These particles of opal are much more likely to cause cell impairment than are particles of crystalline silica (quartz), even though the quartz particles are slightly harder. They contrast significantly in shape and specific gravity relative to quartz particles, and their penetrative potentialities are infinitely greater. Furthermore, among the constituents obtained from the bagasse, quartz is wanting and it is not a common component of dusts in the region where the sugar cane was grown.

That opal is evidently not very readily nor rapidly soluble is indicated by the work of Lovering (1959, p. 792) who found that over several months duration, the solubility of opal in markedly alkaline or acidic solutions ("humic acids") ranged between 20 and 80 parts per million. Moreover, among the many thousands of opal phytoliths examined from the faeces of sheep and rabbits, and from the rumen of the sheep (Baker, Jones and Wardrop, 1961) under the higher powers of the petrological microscope, none has been noted that revealed indisputable evidence of corrosion by chemical attack in the alimentary tract. Most may not have remained in the alimentary tract long enough for corrosion to be made evident, but others could have remained longer if anchored in place or caught up in partial blockages. Opal phytoliths would have to remain in a particular part of an animal organism for long periods if toxic effects on body cells are to be seriously regarded as due to amorphous silica passing into solution more or less *in situ*.

In summary, the properties and characteristics of opal phytoliths that render them readily available to transport under most circumstances, and hence make them a probable menace to man and animals as a likely cause of mechanical damage to internal organic tissues in particular are :

- (i) Ubiquity and availability in many milieus,
- (ii) Specific gravity of 2.0 to 2.2,

- (iii) Needle-like, jagged and angular shapes of some and variable minute outgrowths on others,
- (iv) Microscopic to sub-microscopic size,
- (v) Hardness of 5.5 to 6.5.

9/ Particles of this nature definitely gain entry into the animal systems (Baker and Jones, 1961) and are known to have left the alimentary tract and to have entered the blood and lymph streams. Some become lodged in lymph nodes (Baker and Jones, 1961), some become filtered out and lodged in the urinary system (Baker, Jones and Milne, 1961). Those already observed in the bronchial lymph nodes of the sheep could partly have had their origin as adventitious particles of an allothigenic character that were inhaled and passed through the pulmonary apparatus, although some could have been derived, likewise as adventitious particles, by filtering out from the lymph stream after having been introduced from the alimentary tract.

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DESCRIPTION OF PLATES

PLATE I

Three separate fields of view in the same microscope mount (in Canada balsam) of opal phytoliths constituting the siliceous residue from sugar cane, San Fernando, Philippine Islands. ($\times 258$) (All microphotographs by A. W. Hounslow).

- A. Several hat-and spool-shaped forms, slender and broader rods and small fragments.
 - B. Large and small rods, occasional needle-like forms, hat-and spool-shaped forms, and fragmented opal phytoliths.
 - C. Mainly fragments with long and shorter needle-like forms (bottom, centre).
-

PLATE II

Additional fields of view of the same microscope mount as in Plate I. ($\times 484$).

- A. Rod-like form with serrated edge and small, sharp-pointed outgrowths (centre), several hat-and stud-shaped forms, some with sharp points, and numerous small fragments.
 - B. Hat-shaped forms, prismatic rod-like and long, slender pointed forms.
-

PLATE III

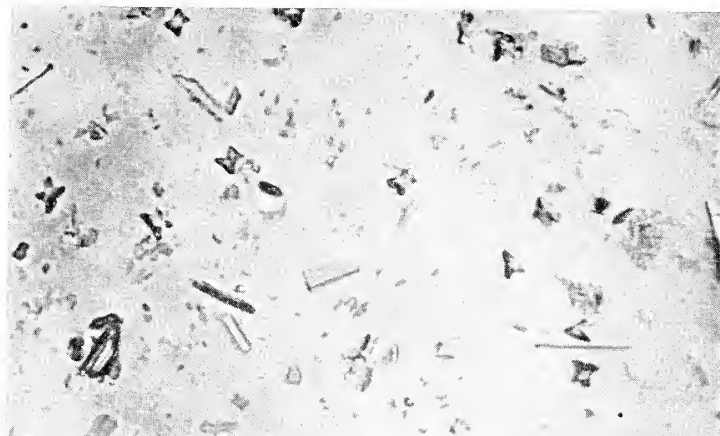
Magnified examples of opal phytoliths in same microscope mount as for Plate I. ($\times 1161$).

- A. Long, slender rod ; B, hat-shaped form with notched "screw-head" top, and thin needle-like form (on left).
 - C. Thin, "phantom-like" rod with outgrowths ; D, group of hat-shaped and broader spool-like forms.
 - E. Broken fragment from prismatic rod-like form (top) and hat-shaped forms with notched "screw-head" tops (form on bottom right reveals points of attachment (dark dots)).
 - F. Narrower and broader stud-shaped and hat-shaped forms.
 - G. Slender, stud-shaped form (top) and portion of rod with rounded termination showing one small, sharp outgrowth.
-

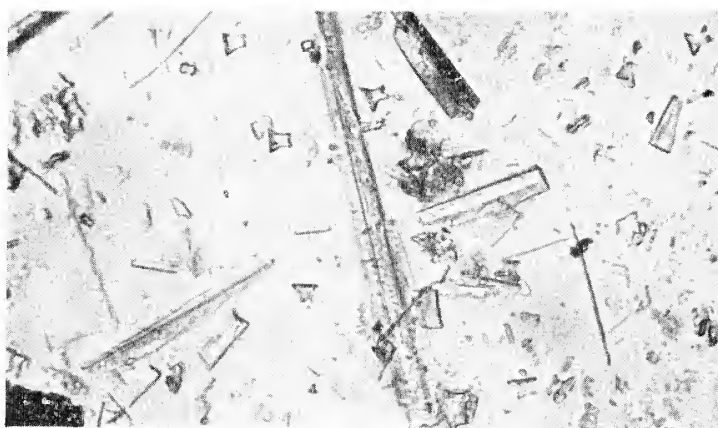
PLATE IV

A sintery residue from the furnace in which bagasse is burned at the Patupanga Sugar Development Co's refinery, San Fernando, Luzon Island, Philippine Islands ($\times 3.2$). (Photograph by K. L. Williams).

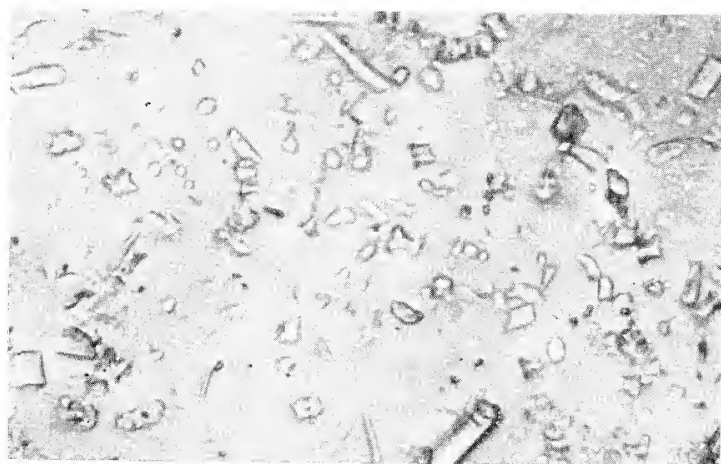
A



B

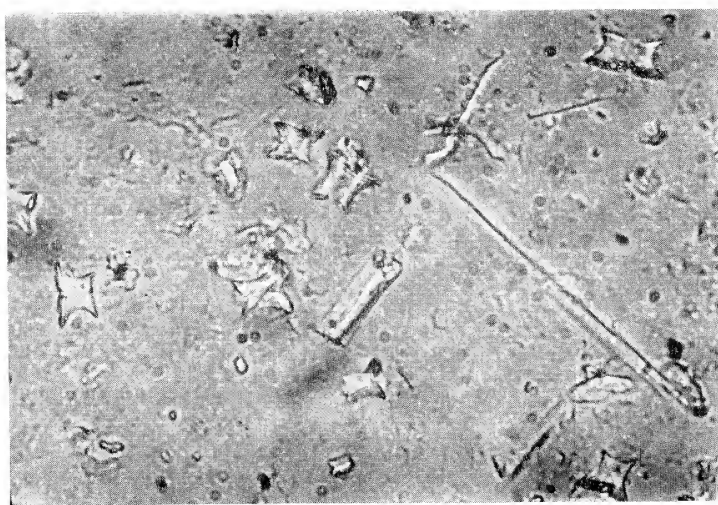


C



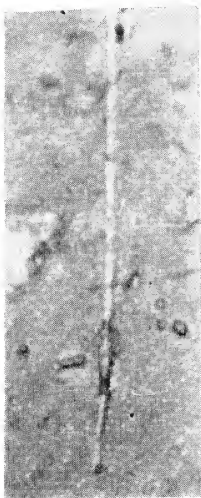


A



B

A



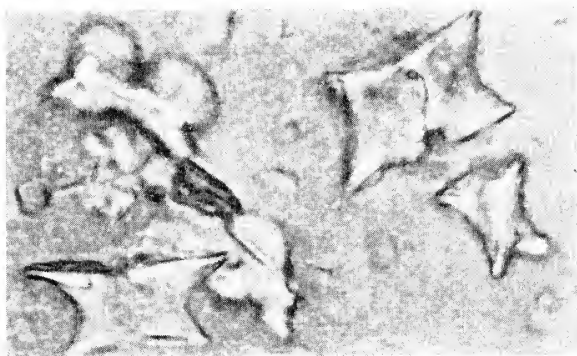
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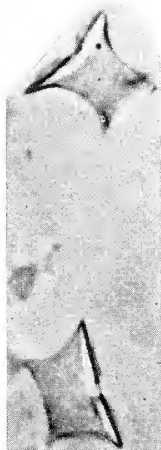
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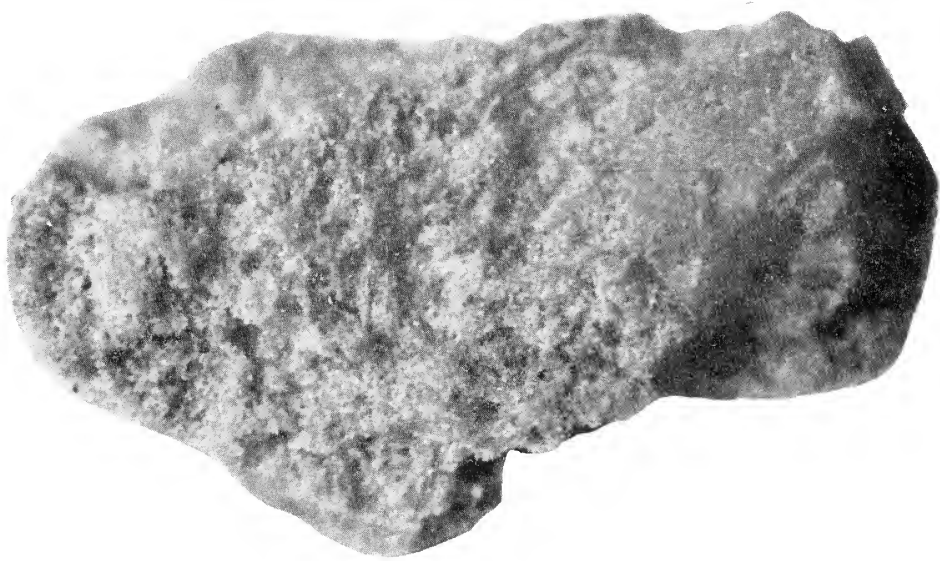
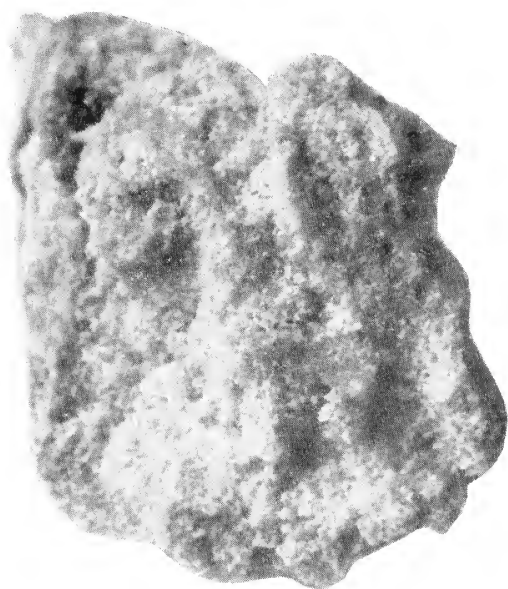
E



F



G



SOME UPPER TRIASSIC HEMIPTERA FROM QUEENSLAND

J. W. EVANS

Australian Museum, Sydney

Fossil insects are known from two localities in Southern Queensland, one in the neighbourhood of Ipswich and the other at Mt. Crosby, and the insect-bearing strata in both areas are of Upper Triassic age.

In this article particulars are given of a collection of 41 wings of fossil Hemiptera from the Mt. Crosby beds. These have been made available to me for study by Mr. F. A. Perkins of the Entomology Department of the University of Queensland to whom thanks are expressed. The present collection brings the total number of wings of Hemiptera recorded from the Upper Triassic of Queensland to 106. Of this number 6 are of cicadoids, 32 cicadelloids, 36 cercopoids and 32 Heteroptera (Tillyard, 1918, 1919, 1921, 1922, 1923, Evans, 1956).

Many of the specimens in the new collection are of species which have been described previously but several of these, nevertheless, are of greater interest than those specimens which represent new species. This is because they provide hitherto unrecorded information of special significance.

Superfamily CICADELLOIDEA

In the majority of described forewings of Upper Permian cicadelloids and in several Triassic ones, the 2 principal branches of *M* are not linked by a cross-vein. Such a cross-vein, which forms a closed cell is, however, present in the forewings of some cicadelloids described from the Triassic of Queensland and the Jurassic of Europe. Formerly I have regarded this characteristic as of special importance, and have used it, together with other features, in defining a Family, the Chiliocyclidae (Evans, 1956).

The genus, *Chiliocycla* Tillyard is, in a later section of this work, transferred to the Cercopoidea hence this family name is no longer an appropriate one to comprise cicadelloids.

The establishment of family groupings based solely on wings is often a matter more of convenience than an expression of known evolutionary distinctiveness. Accordingly, and because the presence of a cell enclosed by the branches of *M* may in

fact lack special significance, the wings of all cicadelloids which are illustrated in the following pages are ascribed to species and to genera but not to particular Families. Furthermore, since the true limits of genera based solely on wing venation must in most instances remain uncertain, and in order to avoid unessential generic nomenclature, such species as are described below as new are all ascribed to previously described genera.

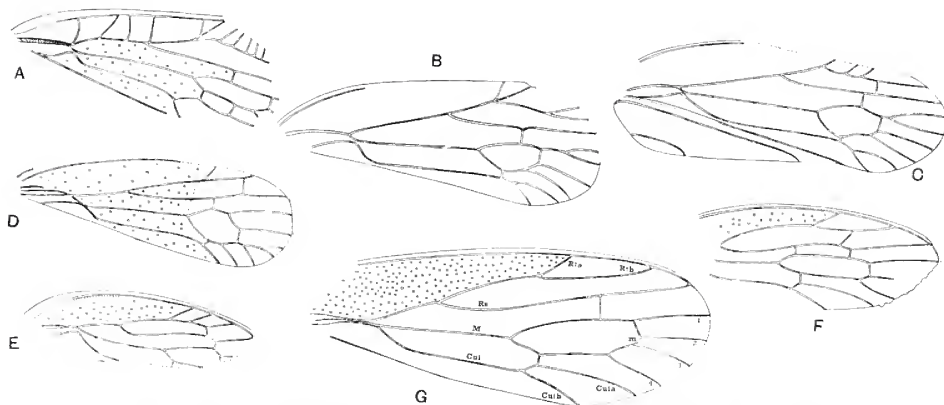


Figure 1. A, *Mesocicadella punctata* ;
C, *M. perkinsi* ;
E, *Triassocotis australis* ;
G, *Triassocotis amplicata*.

B, *Mesothymbris perkinsi* ;
D, *Hylicella colorata* ;
F, *Triassocotis stricta* ;

MESOCICADELLA Evans

Aust. J. Zool., 1956, 4, p. 193

TYPE SPECIES.—*Mesocicadella venosa* Evans.

MESOCICADELLA PUNCTATA sp. nov.

Figure 1. A

Length of fragment, 15.5 mm.; greatest width, 6 mm. Surface of tegmen proximally, but of uncertain distal extension, finely punctate.

Holotype tegmen F. 3681, Queensland Museum.

M. punctata resembles the type species in the presence of numerous costal veinlets. It differs in having the veins apically simple instead of being multi-branched.

MESOTHYMBRIS Evans

Aust. J. Zool., 1956, 4, p. 191

TYPE SPECIES.—*Mesothymbris perkinsi* Evans.

MESOTHYMBRIS PERKINSI Evans

Figures 1, B, C

Mesothymbris perkinsi Evans, 1956, *Aust. J. Zool.*, 4, p. 191.

Four specimens are ascribed to this species.

Figure 1, B. F. 3684, Queensland Museum. Length of tegmen, 9 mm.; greatest width, 3.2 mm.; surface indeterminate. Differs from the Holotype tegmen in having 2 less veinlets between R_1a and R_1b and in having a cross-vein between the anterior and posterior branches of M .

Figure 1, C. F. 3682, counterpart F. 3683, Queensland Museum. Length of tegmen, 9 mm.; greatest width, 3 mm.; surface, especially the clavus, punctate. Differs from the Holotype tegmen in being more complete, in having an enclosed cell between the anterior and posterior branches of M and in minor details in respect to the branching of R_1 . Two unfigured specimens (12 and S1, S1A, Department of Entomology, University of Queensland), both 9 mm. in length. In the former, R_1a and R_1b are present as single veins, while in the latter there are 2 additional veinlets between R_1a and R_1b . S1, S1A, has a fragment of a hind-wing on the same piece of rock.

MESOTHYMBRIS WOODWARDI Evans*Mesothymbris woodwardi* Evans, 1956, *Aust. J. Zool.*, 4, p. 191.

S. 18 Department of Entomology, University of Queensland. Length of tegmen, 7 mm.; greatest width, 3 mm.

HYLICELLA Evans*Aust. J. Zool.*, 1956, 4, p. 195TYPE SPECIES.—*Hylicella colorata* Evans.**HYLICELLA COLORATA** Evans

Figure 1, D

Hylicella colorata Evans, 1956, *Aust. J. Zool.*, 4, p. 195.

Five specimens are ascribed to this species.

F. 3686, Queensland Museum. Length of tegmen, 12 mm.; greatest width, 4 mm.; surface of basal two-thirds, coriaceous, punctate. In the description of the Holotype tegmen it was stated that it had an apparent nodal line, although this was not shown in the accompanying illustration. Such a transverse division of the tegmen, which may represent no more than a change of texture, is shown in figure 1, D. This tegmen differs from the Holotype in having only a single cross-vein r and in the presence of an additional vein between the arms of Cu_1a and Cu_1b .

Other specimens (Department of Entomology, University of Queensland) (6), 11 mm.; venation as in figure 1, D; (2, 2A), 11 mm.; venation as in Holotype; (3, 24), basal two-thirds of tegmen.

TRIASSOSCELIS ANOMOLA Evans

Triassoscelis anomola Evans, 1956, *Aust. J. Zool.*, 4, p. 192.

1, 1A, Department of Entomology, University of Queensland.

TRIASSOCOTIS Evans

Aust. J. Zool., 1956, 4, p. 194.

TYPE SPECIES.—*Triassocotis australis* Evans.

TRIASSOCOTIS AUSTRALIS Evans

Figure 1, E

Triassocotis australis Evans, 1956, *Aust. J. Zool.*, 4, p. 194.

F. 3687, Queensland Museum. Length of fragment, 6 mm. Costal area of impression of ventral surface of tegmen, coarsely punctate. Differs from the Holotype tegmen in having an additional branch of R_1 and in the more distal position of cross-vein $r-m$.

TRIASSOCOTIS STRICTA sp. nov.

Figure 1, F

Length of tegmen, 8.2 mm.; costal area coarsely punctate. Holotype F. 3688, Queensland Museum.

Differs from the tegmen of *T. australis* in R_1 having only 2 branches, the greater proportional length of R_s , the presence of an additional cross-vein $r-m$ and in M having 4 instead of 3 apical branches.

TRIASSOCOTIS AMPLICATA sp. nov.

Figure 1, G

Length of tegmen, 12 mm.; greatest width, 4 mm.; costal area coarsely punctate.

Holotype, F. 3689, Queensland Museum.

Differs from the tegmen of the type species, and that of *T. stricta*, in size; in the more rounded apex; from the former in R_1 having 2 instead of 4 branches and from the latter in M having 3 instead of 4 apical branches.

Superfamily CERCOPOIDEA

Formerly the forewings of 8 species of Australian fossil Homoptera have been ascribed to this Superfamily and they have been placed in 7 genera comprised in 3 families, of which two are extinct (Evans, 1956, 1958). The wings of seven of these insects came from Upper Triassic strata in Queensland, while one was from the Belmont beds in New South Wales, which are of Permian age.

Opinions differ in respect to the correct systematic position of some of these fossils. Thus, Bekker-Migdisova (1949) has described the wing of an insect from Upper Triassic deposits in central Asia (*Mesotraxis reducta* B.M.) which she has ascribed to the family Flatidae (Fulgoroidea). This wing very closely resembles that of *Dysmorphoptiloides elongata* Evans, from the Upper Triassic of Queensland, which I have regarded as that of a cercopoid (Evans, 1956, 1957). Another wing, also from the Mt. Crosby beds, which I had ascribed to the Cercopoidea (Evans, 1956) but not named, since it is known only from an illustration, the whereabouts of the figured specimen being unknown, has been named *Prosbolopsites tillyardi* by Bekker-Migdisova (1960) who regards the insect from which it was derived as being of uncertain position.

It is necessary, because of these differences of interpretation, before describing fossil wings which supposedly belonged to the Cercopoidea, once more to discuss certain features of the forewings of Recent representatives of this superfamily.

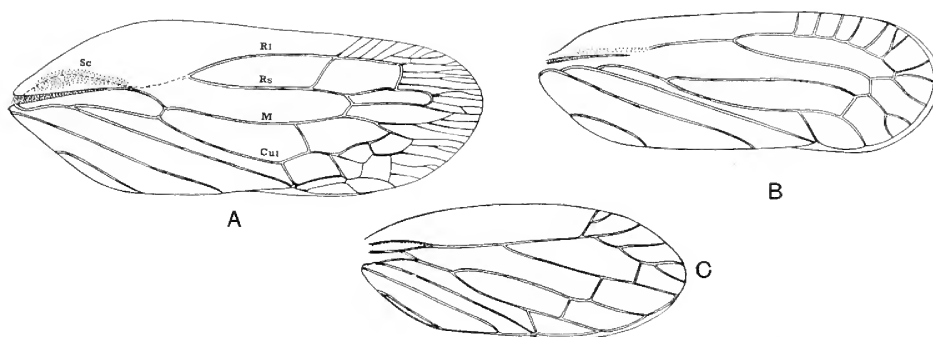


Figure 2. A, *Cosmoscarta incanescens* (Butler); B, *Hemitricphora variabilis* (Distant); C, *Aufulus tripars* Walker

The tegmina of 3 Recent cercopoids are illustrated in figure 2, and attention is drawn to the following features: an extensive costal area; a short *Sc* which curves distally towards the base of *R*; a multi-branched *R*₁, of which some of the branches may be at right angles and others parallel with the costal margin; *Rs* arising from *R* nearer to the base of the tegmen than the apex and sometimes meeting with *R*₁ ante-apically; *M* with 2 apical branches, as a single vein, or, in a reticulate condition

and either linked to Cu_1 by a cross-vein, or else, proximally incorporated in the same vein as Cu_1 ; Cu_1 long and curved. An additional important characteristic of the tegmina of cercopoids is that they may be coarsely punctate and rugose.

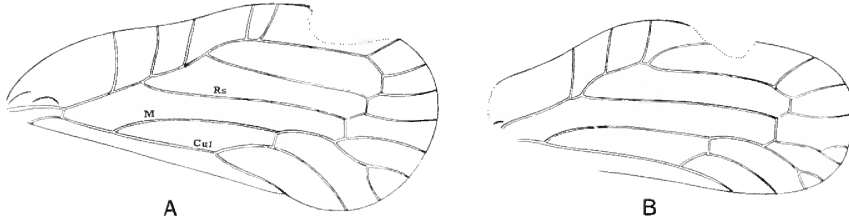


Figure 3. A, *Trifidella perfecta*;

B, *T. perfecta*;

Family **CERCOPIDAE**

TRIFIDELLA Evans

Aust. J. Zool., 1956, 4, p. 215

TYPE SPECIES.—*Trifidella perfecta* Evans.

TRIFIDELLA PERFECTA Evans

Figure 3. A, B

Trifidella perfecta Evans, 1956, *Aust. J. Zool.*, 4, p. 216.

Figure 3A. F. 3690, counterpart F. 3691, Queensland Museum.

Length of tegmen, 8 mm.; greatest width, 3.8 mm.; surface coarsely rugose. Differs from Holotype tegmen principally in the absence of M_1 and M_2 as short, separate veins, in having M_3 and M_4 more fully developed and in having the base of $M + Cu_1$ separated from R by a cross-vein.

Figure 3, B. F. 3692, Queensland Museum. Length of tegmen, 7 mm.; whole tegmen coarsely rugose.

Family **DYSMORPHOPTILIDAE**

DYSMORPHOPTILOIDES Evans

Aust. J. Zool., 1956, 4, p. 218

TYPE SPECIES.—*Dysmorphoptiloides elongata* Evans.

DYSMORPHOPTILOIDES ELONGATA Evans

Dysmorphoptiloides elongata Evans, 1956, *Aust. J. Zool.*, 4, p. 219.

There are 6 wings of this species in the collection, but none differs appreciably from those previously illustrated: 16, 16A; S3, S3A; S14, S14A; S2; S7, S7A; 14 (Department of Entomology, University of Queensland).

Family **EOSCARTERELLIDAE****EOSCARTERELLA** Evans*Aust. J. Zool.*, 1956, 4, p. 220.TYPE SPECIES.—*Eoscarterella media* Evans.**EOSCARTERELLA MEDIA** Evans*Eoscarterella media* Evans, 1956, *Aust. J. Zool.*, 4, p. 221.*Probolopsites tillyardi* Bekker-Migdisova, 1960 76, p. 90 (syn. nov.)

SS, S8A, Department of Entomology, University of Queensland. Length of tegmen, 10 mm.; greatest width 5 mm., surface rugose. It now seems certain that the wing illustrated, but not named, by Tillyard (Tillyard, 1936) was that of an insect belonging to the same species as that described by me as *Eoscarterella media*.

The additional specimen of the tegmen recorded above is not figured because the venation is, in part, confused by the presence of an underlying hind wing. It is, however, sufficiently distinct to enable it to be seen that $M_1 + 2$ form a single vein and that M_3 and M_4 are separate veins. It thus presents a venational condition which is intermediate between Tillyard's illustration and that figured for the holotype of *E. media*.

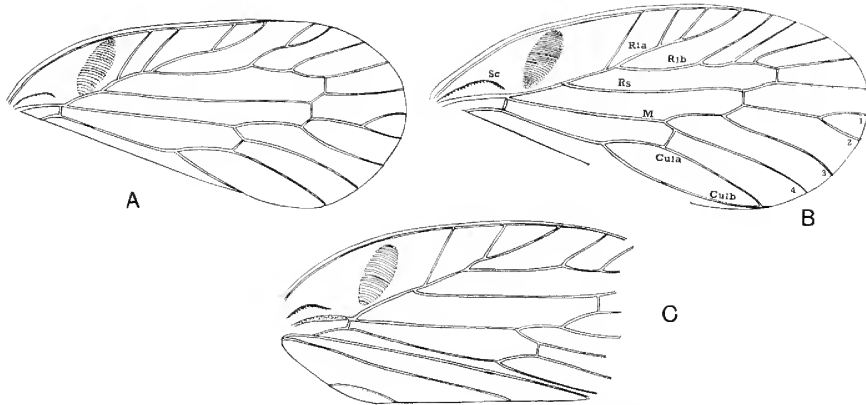


Figure 4. A, *Eoscartoides bryani* ;
C, *E. bryani*.

B, *E. bryani* ;

EOSCARTOIDES Evans*Aust. J. Zool.*, 1956, 4, p. 220TYPE SPECIES.—*Eoscartoides bryani* Evans.

EOSCARTOIDES BRYANI Evans

Figures 4, A, B, C

Eoscartoides bryani Evans, 1956, *Aust. J. Zool.*, 4, p. 221.

Eleven wings of insects belonging to this species are contained in the collection. Every one of them has a feature which was not noticed at the time the original description was made. This is the presence, in the proximal costal area of the tegmen, of a well-defined, striated, stridulating area. An examination of several Recent cercopoids has disclosed no trace of the existence of such an area. It would seem that stridulation could take place by the rubbing of the apices of the hind femora against the under surface of the tegmina.

Figure 4, A. F. 3693, counterpart F. 3694, Queensland Museum. Length of tegmen, 12 mm.; greatest width, 5 mm.; surface of tegmen evenly, finely, punctate.

Figure 4, B. F. 3695, counterpart F. 3696, Queensland Museum. Length of tegmen, 12 mm.; greatest width 5 mm.

Figure 4, C. F. 3697, counterpart F. 3698, Queensland Museum. Length of fragment, 10 mm. Clavus present with separate anal veins.

The 3 tegmina which are illustrated differ from those of the holotype tegmen in being more complete and in having some additional cross-veins. Specimens in Department of Entomology, University of Queensland : S4, S5, S5A, S9 ; S10, S10A, S13, S13A, S15 ; S17, S17A, S19, S19A.

Family **CHILIOCYCLIDAE****CHILIOCYCLA** Tillyard*Proc. Linn Soc., N. S. W.*, 1919, 44, p. 868TYPE SPECIES.—*Chiliocyclus scolopoides* Tillyard.**CHILIOCYCLA SCOLOPOIDES** Tillyard*Chiliocyclus scolopoides* Tillyard, 1919, *Proc. Linn. Soc. N.S.W.*, 44, p. 868.*Chiliocyclus scolopoides* Tillyard, 1923, *Proc. Linn. Soc. N.S.W.*, 47, p. 460.*Chiliocyclus scolopoides* Tillyard, Evans, 1956, *Aust. J. Zool.*, 4, p. 209.

The position of this insect, which is known by the existence of 2 tegmina described by Tillyard from the Ipswich beds has long been problematical. Tillyard placed it in the Scytinopteridae and formerly, though recognizing that it seemed to have certain cercopoid features, I have likewise regarded it as belonging to the Cicadelloidea. Further consideration, and the study of other fossil tegmina, suggests that it is best regarded as the wing of a cercopoid for the following reasons : the tuberculate surface ; the possible presence of a distinct, short *Sc* ; *Rs*. arising from *R*,

nearer to the base of the tegmen than the apex ; the presence of a proximal cross-vein $m-u$; the shape of the arms of Cu_1 . It is assumed that the cell enclosed by the arms of M represents a development parallel with a similar one found in certain Triassic and Jurassic cicadelloids and does not denote close relationship.

DISCUSSION OF THE CERCOPOIDEA

The principal characteristics of the tegmina of Recent cercopoids have already been discussed and illustrated. Attention is drawn to the following resemblances between the tegmina of some living cercopoids and those of insects which are believed to have belonged to the same superfamily : coarse texture ; extensive basal costal area ; R_1 with numerous branches ; early departure of Rs from R ; R_1 and Rs sometimes confluent ante-apically ; basal fusion of M and Cu_1 or, if these veins are separate, their attachment to each other by a basal cross-vein ; curved shape of Cu_1a .

It is claimed that the tegmina which have been ascribed above to the Cercopoidea cannot have been those of either cicadelloids or fulgoroids for the following reasons : while the surface of the insects in both these groups may be coriaceous and punctate, they are never coarsely rugose ; in cicadelloids Rs usually arises from R in a more distal position and when the separation of these 2 veins is proximally situated (as for example in *Hylicella colorata*) then R_1 is less extensive ; while in Permian and Triassic cicadelloids M may be basally associated with R , as it is also in most Recent forms, it is never, except in the Membracidae, basally fused with Cu_1 . Moreover, in generalised membracids R , M and Cu_1 are distinct for the whole of their lengths and R_1 never has more than 2 branches. While in the Fulgoroidea R_1 may be multi-branched and Rs depart from R nearer to the base of the tegmen than the apex, M is almost invariably multi-branched. In the fossils under discussion M however shows a trend in the direction of reduction and not of increase. Finally, in generalised Fulgoroids M is always separate from Cu_1 and the latter vein usually separates into Cu_1a and Cu_1b in a proximal position. Some Fulgoroids stridulate and no Recent cercopoids have been recorded as doing this, but this factor need not be of any phylogenetic significance.

Suborder **HETEROPTERA**

Family **ACTINOSCYTINIDAE**

PLATYSCYTINELLA Evans

Aust. J. Zool., 1956, 4, p. 245

TYPE SPECIES.—*Platyscytinella paradoxa* Evans.

PLALYSCYTINELLA PARADOXA Evens

Platyscytinella paradoxa Evans, 1956, *Aust. J. Zool.*, 4, p. 245.

10, 10a, Department of Entomology, University of Queensland.

HETEROSCYTINA Evans*Aust. J. Zool.*, 1956, 4, p. 245TYPE SPECIES.—*Heteroscytina tillyardi* Evans.**HETEROSCYTINA TILLYARDI** Evans*Heteroscytina tillyardi* Evans, 1956, *Aust. J. Zool.*, 4, p. 256.

21, 21A ; 23, 23A, Department of Entomology, University of Queensland.

Two insects, which almost certainly belong to the family Actinoscytinidae, have been described from the Triassic of Central Asia and named *Olgamartynovia turanica* B.M. and *Cicadocoris kuliki* B.M. (Bekker-Migdisova, 1958). They have been placed by the author in the family Cicadocoridae, which she ascribed to the Homoptera, Coleorrhyncha.

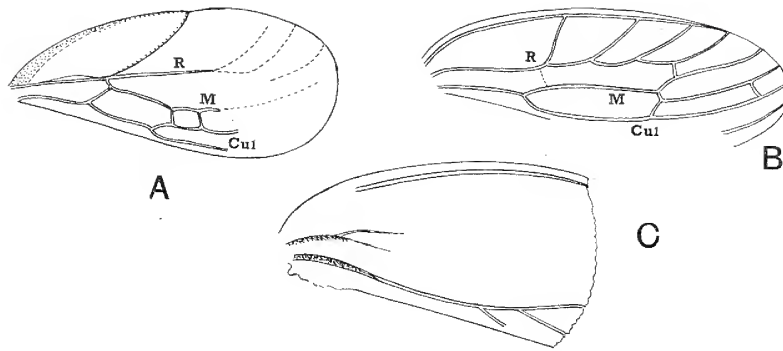


Figure 5. A, *Heteronella marksei* ;
C, fragment.

B, *Heterojassus membranaceus* ;

HETERONELLA gen. nov.

Upper Triassic Heteroptera from Queensland having a well defined costal fracture in the tegmen (Evans, 1950) and with the venation distinct in the basal half of the tegmen only. In the distal half, the veins, which are indistinct, curve towards the costal margin of the tegmen. *R* is well defined basally and is proximally incorporated in the same vein as *M*. Apically, *R* seems to have 3 branches and *M* to be a single vein. The 2 branches of *Cu*₁ are elongated and *Cu*₁ is joined to *M* by a wide cross-vein.

TYPE SPECIES.—*Heteronella marksei* sp. nov.**HETERONELLA MARKSEI** sp. nov.

Figure, 5, A

Holotype tegmen, F. 3699, counterpart F. 3700, Queensland Museum.

Length of tegmen, 3.8 mm.; greatest width, 2 mm. It is possible that this forewing may be that of a saldid or an ochterid.

HETEROJASSUS gen. nov.

Upper Triassic Heteroptera from Queensland with membranous tegmina in which *R* is multi-branched and *M* and *Cu*₁ basally form a single vein. There is an enclosed elongate cell between *M* and *Cu*₁ and a wide appendix. All the veins curve towards the anterior corner of the apex of the tegmen.

TYPE SPECIES.—*Heterojassus membranaceus* sp. nov.

HETEROJASSUS MEMBRANACEUS sp. nov.

Figure 5, B

Holotype tegmen, F. 3701, Queensland Museum. Length of tegmen, 5.1 mm.

Superficially this wing might seem to be that of a representative of the Homoptera rather than of the Heteroptera. The lack of *Rs* and the apical directional trend of the veins suggest, however, Heteropterous, rather than Homopterous affinities.

Figure 5, C. F. 3702, Queensland Museum. A fragment of the forewing of a Heteropteron, 5.4 mm. in length, which lacks sufficient characters to justify it being named.

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